

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 582 987 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
09.12.1998 Bulletin 1998/50

(51) Int. Cl.⁶: **B29C 45/77**

(21) Application number: **93112734.4**

(22) Date of filing: **09.08.1993**

(54) Control unit with gain changing means responsive to operating conditions

Kontrolleinheit mit Mitteln zur Anpassung des Verstärkungsfaktor an die Betriebsbedingungen

Unité de contrôle avec des moyens pour changer le gain en fonction des conditions de fonctionnement

(84) Designated Contracting States:
AT CH DE FR GB IT LI

(30) Priority: **10.08.1992 JP 212927/92**

(43) Date of publication of application:
16.02.1994 Bulletin 1994/07

(73) Proprietor:
SUMITOMO HEAVY INDUSTRIES, LTD
Tokyo 100 (JP)

(72) Inventor: **Hiraoka, Kazuo**
Chiba-shi, Chiba-ken (JP)

(74) Representative:
VOSSIUS & PARTNER
Siebertstrasse 4
81675 München (DE)

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Description

This invention relates to an injection molding machine controlled by an electrical servo motor wherein response characteristic and tracking property in the pressure control are improved.

Recently, use has widely been made of an electrical injection molding machine which is driven by a servo motor in place of a hydraulic actuator to inject a resin material into a mold and to manufacture a molded product. In general, the injection molding machine includes an injection unit driven by the servo motor and a controller coupled to the injection unit and the servo motor to control the servo motor by monitoring the injection unit. The injection unit comprises an injection cylinder provided with a hopper and a screw arranged in the injection cylinder. The screw is directly coupled at its rear end to a drive shaft operatively coupled to an injection motor formed by the servo motor. The servo motor rotates the drive shaft to move the drive shaft forwards and backwards. As a result, the screw reciprocates forwards and backwards along a guide bar. A load cell is mechanically coupled to the drive shaft to detect a pressure imposed on the drive shaft.

Description will be made as regards an operation of the injection unit hereinafter.

(1) A resin material is introduced from the hopper into the injection cylinder and is melted into molten resin. The molten resin is conveyed towards a top end portion of the heat cylinder by a predetermined amount by driving the injection motor. This process is referred to as a measuring process. During the measuring process, the screw is slightly retracted due to a back pressure of the molten resin packed into the top end portion of the injection cylinder. The back pressure is detected by the load cell which produces a pressure detection signal representative of the back pressure. The back pressure is controlled by the use of the pressure detection signal in a manner to be described later.

(2) Then, the drive shaft is driven by the injection motor to be moved forwards. A forward end of the screw acts as a piston to inject the molten resin into the mold. This process is referred to as a filling or an injection process. During the injection process, the controller puts the screw into a velocity or speed control mode.

(3) At the end of the injection process, the mold is filled with the molten resin. Then, the controller switches a control mode from the velocity control mode into a pressure control mode. Such a switching operation is called a V-P (velocity to pressure) switching operation. The timing and the way of the switching operation seriously affect the quality of a molded product.

(4) After the V-P switching operation, the molten resin filled in the mold is cooled and solidified under a predetermined pressure. This process is referred to as a holding process. The pressure applied to the resin is controlled by the controller, like the back pressure.

In the injection unit, the holding process (4) is further succeeded by a next measuring process (1) in a next cycle.

On the other hand, a clamping unit is operated to clamp or close the mold during the holding process (4) which is followed by an ejecting process. In the ejecting process, a molded product which has been cooled and solidified is removed or ejected from the mold by opening the mold and by using an ejector mechanism. The mold is thereafter closed again and the ejecting process proceeds to the injection process (2). Thus, the measuring process (1) in the injection unit is carried out simultaneously with the ejecting process in the clamping unit.

During the injection process, a velocity feedback control is carried out by the use of the movement or velocity of the screw. On the other hand, during the holding process, a pressure feedback control is carried out by detecting the reaction force applied to the load cell. Thus, the molding operation is carried out by a combination of the velocity feedback control and the pressure feedback control.

In a conventional pressure control system, an operation pattern signal representative of a target value is produced by an operation pattern generator. For example, such an operation pattern generator is disclosed in JP-A-253319/91. The reaction force applied to the load cell is detected as a pressure detection signal. The pressure detection signal is amplified and then subtracted from the operation pattern signal to produce a first error signal. The error signal is multiplied by a basic gain to produce a multiplication result signal. The multiplication result signal is subjected to compensation calculation to produce a compensation result signal. On the other hand, a velocity detection signal is obtained by amplifying and differentiating a position signal. The velocity detection signal is subtracted from the compensation result signal to produce a second error signal. The second error signal is subjected to compensation calculation and amplified into a torque command signal.

In the conventional pressure control system described above, an operation characteristic in the pressure control is determined with reference to a single basic gain preliminarily selected. With this structure, it is difficult to uniquely define the load in the pressure control system because a wide variety of resin materials and molds are used. In this connection, the gain must be selected at a minimum value in consideration of various conditions. Otherwise, oscillation objectionably occurs in the pressure control system.

When the gain is increased to improve the response characteristic of the pressure control system, a transmission

mechanism from the servo motor to the screw may be oscillated due to the remarkable increase of a backlash or a difference in efficiency between forward and backward movement of the screw. Under these circumstances, the gain is usually selected to be considerably small. This results in deterioration of accuracy and repeatability of the pressure control.

From JP-A-58-011128 an injection moulding machine with a hydraulic actuator controlled by a servo valve is known. It comprises a feedback control system for the injection pressure. A gain of a differential amplifier is increased for compensation of a deterioration of the servo valve.

It is therefore an object of this invention to provide an injection molding machine controlled by an electrical servo motor wherein the response characteristic and tracking property in the pressure control are improved by selecting an optimum gain in accordance with an operating condition.

The object is solved by the features of the claims.

Fig. 1 is a schematic block diagram of an injection unit of a typical injection molding machine;

Fig. 2 is a block diagram for describing a structure of a conventional controller which is applied to the injection molding machine illustrated in Fig. 1;

Fig. 3 is a block diagram for describing a structure of a controller of an electrical injection molding machine according to a first embodiment of this invention;

Fig. 4 is a simplified block diagram of the structure illustrated in Fig. 3;

Fig. 5 is a block diagram illustrating a main portion of the controller illustrated in Fig. 3;

Fig. 6 is a block diagram illustrating a main portion of a controller according to a second embodiment of this invention;

Fig. 7 is a block diagram illustrating a main portion of a controller according to a third embodiment of this invention;

Fig. 8 is a block diagram illustrating a main portion of a controller according to a fourth embodiment of this invention;

Fig. 9 is a block diagram illustrating a main portion of a controller according to a fifth embodiment of this invention;

Fig. 10 is a block diagram illustrating a main portion of a controller according to a sixth embodiment of this invention;

Fig. 11 is a block diagram illustrating a main portion of a controller according to a seventh embodiment of this invention;

Fig. 12 is a block diagram illustrating a main portion of a controller according to an eighth embodiment of this invention; and

Fig. 13 is a block diagram illustrating a main portion of a controller according to a ninth embodiment of this invention.

For a better understanding of this invention, description will at first be made as regards an injection unit of a conventional injection molding machine with reference to Fig. 1.

Referring to Fig. 1, the conventional injection molding machine comprises a servo motor 11 operable as an injection motor, a roller screw 12, and a roller nut 13. The rotation of the servo motor 11 is converted into the linear motion through the roller screw 12 and the roller nut 13 to carry out a filling operation of molten resin. In Fig. 1, the rotation of the servo motor 11 is transmitted to the roller screw 12. With the rotation of the roller screw 12, the roller nut 13 is moved forwards or backwards of Fig. 1. The roller nut 13 is integrally fixed to a slide base 14. The slide base 14 is slidably supported on a pair of guide bars 15 and 16 fixed to a frame (not shown) so as to be moved along the guide bars 15 and 16. With this structure, the slide base 14 conducts a forward or a backward movement together with the roller nut 13. The forward or the backward movement of the slide base 14 is transmitted through a bearing 17 and a pressure sensor (namely, a load cell) 18 to a screw 21 in an injection cylinder 20. To the slide base 14, attached is a position sensor 25 for detecting a position of the screw 21 to produce a position detection signal representative of the position of the screw 21. The position detection signal is given to an amplifier 26 (may be referred to as a first or a position amplifier) and amplified into a first amplified signal which is supplied to a controller 24.

In a measuring process, a resin material is introduced from a hopper 22 into the injection cylinder 20 where the resin material is heated and melted into molten resin.

In an injection process, the screw 21 is moved forwards of Fig. 1 in the injection cylinder 20 to fill a mold (not shown) with the molten resin which has been stored in the injection cylinder 20 during the measuring process. Then, the molten resin is filled in the mold with a pressure applied thereto. At this time, a reaction force is imposed on the load cell 18 against the pressure applied to the molten resin. The reaction force is detected by the load cell 18 to produce a pressure detection signal representative of a detected pressure value. The pressure detection signal is amplified by a load cell amplifier (which will be called a second amplifier) 23 into a second amplified signal to be supplied to the controller 24.

A preset value is also given to the controller 24 by an operator. Under the circumstances, the controller 24 supplies a servo amplifier 27 with an electric current command which corresponds to each process and which is indicative of a torque of the servo motor 11. In response to the electric current command, the servo amplifier 27 varies a drive current

for the servo motor 11 to thereby control an output torque of the servo motor 11.

With the above-mentioned structure, during the injection process, the molten resin is filled in the mold, carrying out velocity feedback control which controls a movement velocity or speed of the screw 12.

During the holding process, the resin in the mold is kept at predetermined pressures by carrying out pressure feedback control by monitoring the reaction force applied on the load cell 18. Thus, both the velocity feedback control and the pressure feedback control should be carried out during the molding operation mentioned above.

Referring to Fig. 2 in addition to Fig. 1, the controller 24 comprises a differentiator 24-1, an operation pattern generator 24-2, a first subtractor 24-3, a multiplier 24-4, a pressure control compensator 24-5, a second subtractor 24-6, and a velocity control compensator 24-7.

As described above, the controller 24 is given the first and the second amplified signals from the amplifier 26 and the load cell amplifier 23, respectively. The controller 24 is also given the preset value by the operator. With respect to the preset value, the operation pattern generator 24-2 generates an operation pattern signal S_r representative of a target value. The operation pattern signal S_r is selected so as to improve a tracking property of pressure feedback control and to avoid drastic variation of a pressure in the mold.

In Fig. 2, the second amplified signal (depicted at S_p) from the load cell amplifier 23 is supplied to the first subtractor 24-3 and subtracted from the operation pattern signal S_r to produce a first error signal e . The first error signal e is delivered to the multiplier 24-4 and multiplied by a gain signal S_a having a basic gain K_0 to produce a multiplication result signal S_m . The multiplication result signal S_m is supplied to the pressure control compensator 24-5 and subjected to compensation calculation to produce a first compensation result signal S_v . The first compensation result signal S_v is delivered to the second subtractor 24-6.

On the other hand, the first amplified signal from the amplifier 26 is differentiated by the differentiator 24-1 to produce a velocity detection signal S_d . The velocity detection signal S_d is delivered to the second subtractor 24-6. In the second subtractor 24-6, the velocity detection signal S_d is subtracted from the first compensation result signal S_v to produce a second error signal e' . The second error signal e' is supplied to the velocity control compensator 24-7 and subjected to compensation calculation to produce a second compensation result signal. The second compensation result signal is amplified by the servo amplifier 27 and supplied to the servo motor 11 as a torque (current) command.

As described in the preamble of the specification, the above-mentioned conventional controller 24 is disadvantageous in accuracy and reproducibility in the pressure control because the operation characteristic is determined by the use of a single basic gain preliminarily selected.

Referring to Fig. 3, description will now be mainly made as regards a controller 24 according to a first embodiment of this invention. In Fig. 3, similar parts are designated by like reference numerals as those described with reference to Fig. 2. The controller 24 has a structure similar to the conventional controller illustrated in Fig. 2 and further comprises a pattern differentiator 31, a gain multiplier 32, and a gain adder 33.

The controller 24 is supplied with the first amplified signal and the second amplified signal S_p from the amplifier 26 and the load cell amplifier 23, respectively. The first amplified signal is differentiated by the differentiator 24-1 to produce the velocity detection signal S_d which is supplied to the second subtractor 24-6 while the second amplified signal S_d is supplied to the first subtractor 24-3, in the manner similar to that described in conjunction with Fig. 2. The operation pattern generator 24-2 generates the operation pattern signal S_r which is also supplied to the first subtractor 24-3.

On the other hand, the operation pattern signal S_r is differentiated by the pattern differentiator 31 and multiplied by a first gain K_1 to produce a pattern differential signal. The pattern differential signal is supplied to the gain multiplier 32 and multiplied by the basic gain K_0 to produce a gain multiplication signal. The gain multiplication signal is supplied to the gain adder 33 and added to the basic gain K_0 to produce a gain signal S_g . The gain signal S_g is supplied to the multiplier 24-4 and multiplied by the first error signal e to produce the first multiplication result signal S_m . The first multiplication result signal S_m is supplied to the pressure control compensator 24-5 and subjected to compensation calculation to produce the first compensation result signal S_v .

The first compensation result signal S_v is supplied to the second subtractor 24-6. The second subtractor 24-6 subtracts the velocity detection signal S_d from the first compensation result signal S_v to produce the second error signal e' . The second error signal e' is supplied to the velocity control compensator 24-7 and subjected to compensation calculation to produce the second compensation result signal. The second compensation result signal is amplified by the servo amplifier 27 and supplied to the servo motor 11 as a torque (current) command.

Temporarily referring to Fig. 1, it is noted that the electrical injection molding machine has different stability limits during the pressure control due to a nonlinear component, such as a backlash and a nonviscous friction between the roller screw and the roller nut. Such a nonviscous friction is variable regardless of a velocity. Specifically, the stability limits are varied in dependence upon whether the screw or the transmission mechanism is stopped or moved, whether operation is carried out at a low speed or a high speed, and so on. For example, the stability limit takes a low value when the screw or the transmission mechanism is stopped, otherwise, the stability limit becomes high. This means that instability or oscillation is liable to occur during the low stability limit.

Let the backlash of the screw be considered as the nonlinear component. While the screw is moved in a certain

direction, the backlash is absorbed and disappears because a play or gap for the backlash is squeezed due to force pressing in the certain direction. In addition, a friction load is continuously smoothly varied because the moving direction is invariable. At any rate, the stability is increased as the movement becomes large. Thus, the stability limits are varied in dependence upon the nonlinear component which has a similar property.

In view of the above, in this embodiment, the operation condition of the driving system is indirectly monitored with reference to the differential value obtained by differentiating the operation pattern signal. The gain in the pressure control system is changed by the use of the differential value.

The control system illustrated in Fig. 3 comprises a velocity feedback control system formed by the position detector 25, the amplifier 26, the differentiator 24-1, the second subtractor 24-6, the velocity control compensator 24-7, the servo amplifier 27, and the servo motor 11 in addition to the pressure control system. The velocity feedback control system can be simplified into a velocity control system which is assumed to have a response speed considerably greater than that of the pressure control system. Herein, it is also assumed that the pressure control compensator 24-5 is implemented by a proportional compensator having a second gain K2 and that a specific one of the components is selected from the loads imposed on the resin and is represented as an integral element of a gain K3 related to the movement velocity of the screw.

Under the circumstances, the structure in Fig. 3 is simplified into that illustrated in Fig. 4. The reference symbol S in the resin load 36 represents a Laplace operation. The velocity control system 24-7 is represented as a quick response system which has a gain equal to unity in Fig. 4. A relationship between the operation pattern signal Sr and the first compensation result signal Sv is defined by a transfer function and is given by Equation (1):

$$Sv/Sr = K0 \cdot K2 \cdot S/(S + K0 \cdot K2 \cdot K3) \quad (1)$$

Equation (1) indicates that the velocity is obtained by differentiating the operation pattern signal Sr. In other words, differentiation of the operation pattern signal Sr gives a parameter which, although indirectly, indicates the state or the dimension of the operation of the screw during the pressure control.

In this embodiment, it is assumed here that a control gain becomes equal to K10 which corresponds to the stability limit given when the pressure control system is put in a stopped or a stable state. When the operation is performed at a maximum magnitude, let the operation pattern signal Sr have a variation ratio of ΔSr_{max} . In this situation, the control gain is increased at an increment ratio x with respect to the control gain K10.

Referring to Figs. 3 and 4, it is assumed here that:

$$K0 = K10$$

and

$$K1 = x/\Delta Sr_{max}.$$

In this event, the gain signal Sq is given by:

$$Sg = K10 \text{ (in the stopped state)}$$

and

$$Sg = (1 + \Delta Sr_{max} \cdot K1) \cdot K10 = (1 + x) \cdot K10 \text{ (in the maximum operation state)}.$$

Herein, the gain signal Sg represents a function indicative of a boundary which is capable of improving the control gain without exceeding the stability limits. The multiplier 24-4 carries out feedback control by the use of the gain signal Sg.

Fig. 5 is a view which is similar to Fig. 3 except that a subject portion alone is illustrated in detail with the remaining portions simplified. A combination of the operation pattern generator 24-2 and the pattern differentiator 31 in Fig. 3 serves as a boundary detecting unit 42. In Fig. 5, a controlled object molding unit 41 represents a pressure control system in the injection molding machine wherein the filling operation is carried out by converting the rotation into the linear motion through the roller screw and the roller nut as illustrated in Fig. 1.

In addition, it is assumed that the pressure control system contains a nonlinear component or element which can not linearly increase the feedback compensation gain and, as a result, which is specified by a nonlinear characteristic.

The boundary detecting unit 42 detects a boundary of each element of the controlled object divided by nonlinearity of the controlled object molding unit 41. More specifically, the boundary detecting unit 42 divides the nonlinear characteristic of the nonlinear component into a plurality of partial characteristics each of which may be regarded as a linear characteristic. Each boundary is interposed between two adjacent ones of the partial characteristics.

A combination of the gain multiplier 32 and the gain adder 33 acts as a gain changing unit 46. The gain changing unit 46 is supplied with differential values of successive operation pattern signals and operated to successively change the basic gain K0 supplied from a basic gain providing unit 45 with respect to the basic value when the differential value is equal to zero.

Figs. 6 through 13 show schematic block diagram illustrating subject portions of controllers according to second through eighth embodiments of this invention. In these figures, similar parts are designated by like reference numerals.

Referring to Fig. 6, the controlled object molding unit 41 represents the pressure control system in the injection molding machine wherein the filling operation is carried out by converting the rotation into the linear motion through the roller screw and the roller nut as illustrated in Fig. 1. The control system is assumed to contain a nonlinear element or component like in Fig. 5. In the example being illustrated, a gain memorizing unit 43 is for memorizing an optimum control gain corresponding to an upper limit level for each divided element of the controlled object so that the stability of the pressure control system is not degraded. A gain selecting unit 44 selects the optimum gain from the gain memorizing unit 43 in response to the output signal of the boundary detecting unit 42.

Referring to Fig. 7, no direct detection can be made about the boundary divided by nonlinearity of the controlled object molding unit 41. In this event, the boundary detecting unit 42 is supplied with an indirect detection value indirectly indicative of the state of the molding machine by means of correlation. Subsequent operation is similar to that described in conjunction with Fig. 6.

Referring to Fig. 8, the controlled object molding unit 41 does not contain any obvious boundary of nonlinearity but exhibits consecutive variation. In this event, the boundary detecting unit 42 controls the gain changing function unit 46 by the use of a series of functions to change the ratio with respect to the basic gain K0 supplied from the basic gain providing unit 45.

Referring to Figs. 9 through 12, these embodiments are particularly effective in preventing oscillation caused by phase lag due to backlash or oscillation caused by the difference in efficiency of the roller screw and the roller nut between a pressurized state and a depressurized state.

Referring to Fig. 9, the boundary detecting unit 42 is supplied with a control error, namely, a pressure error during the pressure control in the controlled object molding unit 41. The boundary detecting unit 42 is also supplied from a differentiator 47 with a differential value obtained by differentiating the pressure error. In response, the boundary detecting unit 42 controls the gain selecting unit 44. Thus, the gain is changed by the use of the boundary on a plane.

Referring to Fig. 10, a state detecting unit 50 for detecting the state of the controlled object is formed by a combination of a screw velocity detector 51 for detecting the movement velocity of the screw during the pressure control in the controlled object molding unit 41, a reference value generator 52, and an absolute value comparator 53. The absolute value comparator 53 compares a reference value supplied from the reference value generator 52 and an output signal of the screw velocity detector 51 to produce a comparator output signal. The comparator output signal is detected by the boundary detecting unit 42 to control the gain selecting unit 44. Thus, the gain is controllably changed in the vicinity of the stopped state and the others.

Referring to Fig. 11, the state detecting unit 50 for detecting the state of the controlled object is formed by a combination of the screw velocity detector 51 for detecting the movement velocity of the screw during the pressure control in the controlled object molding unit 41, a motor velocity detector 54 for detecting the velocity of the driving motor, and a subtractor 55. The subtractor 55 is supplied with output signals of the screw velocity detector 51 and the motor velocity detector 54 and detects the difference between the movement or the velocity of the screw and the rotation or the velocity of the motor. With reference to the difference thus detected, the boundary detecting unit 42 controls the gain selecting unit 44 to controllably change the gain.

Referring to Fig. 12, the state detecting unit 50 for detecting the state of the controlled object is formed by a combination of a load pressure detector 56 and a motor torque detector 57. During the pressure control in the controlled object molding unit 41, the boundary detecting unit 42 controls the gain selecting unit 44 in accordance with the polarities of a motor driving current and a pressure load. Thus, the gain is controllably changed.

Referring to Fig. 13, the boundary detecting unit 42 comprises a timer 63 for measuring the lapse of time from the start of injection during the pressure control in the injection molding machine by counting clock pulses. Supplied with the basic gain K0 from the basic gain providing unit 45, the gain changing unit 46 successively changes the gain, as the count proceeds, with respect to the basic value corresponding to a stability limit when the resin in the mold has completely been solidified.

As described above, according to this invention, in the pressure control where the load imposed on the resin is a substantially integral load, the optimum gain is selected by monitoring the operating condition. Thus, it is possible to provide an accurate and reproducible pressure control. Specifically, it is possible to provide an excellent tracking property even in the operating condition in which the operation is controllably followed by changing the gain from a small level in the stopped state to a large level in a large movement state.

In the foregoing description, this invention is applied to the pressure control in the injection molding machine. However, this invention is also applicable to a back pressure control, a screw rotation control, a mold open/close velocity

control, a clamping force control, an injection pressure control, or the like.

Claims

- 5 1. Injection molding machine controlled by an electrical servo motor (11) comprising gain providing means (45) for providing a gain to the current supplied to said motor, boundary detecting means (42) for dividing a nonlinear characteristic of a nonlinear component of coupling means between said motor and an injection cylinder (20) to detect each boundary of said nonlinear characteristic and to produce a boundary signal representative of each boundary, and gain changing means (46) responsive to said boundary signal for changing said gain of said gain providing means (45) with reference to said boundary signal.
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2. Injection molding machine as claimed in Claim 1, wherein said gain providing means (45) is for providing a basic gain as said gain;
15 said boundary detecting means (42) including:
operation pattern producing means (24-2) for producing an operation pattern; and
differentiating means (31) for calculating a differential value of said operation pattern to produce said differential value as said boundary signal;
20 said gain changing means (46) being responsive to said differential value of said operation pattern to successively change said basic gain with reference to a value calculated when said differential value is equal to zero.
3. Injection molding machine as claimed in Claim 1 or 2, said molding machine comprising a mold into which resin is injected;
25 said gain providing means (45) being providing a basic gain;
said boundary detecting means (42) including:
30 measuring means (63) for measuring a lapse of time from the start of injection to produce a measurement result signal indicative of said lapse of time;
said gain changing means (46) being responsive to said measurement result to successively change said basic gain with reference to a stability limit gain obtained when said resin has completely been solidified in said mold.
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4. Injection molding machine controlled by an electrical servo motor (11) comprising:
state detecting means (50) for detecting a result of control of said injection molding machine to produce a detection signal indicative of said result of control;
40 gain memorizing means (43) for memorizing a plurality of gains of said motor (11);
boundary detecting means (42) supplied with a signal from said state detecting means for dividing a nonlinear characteristic of a nonlinear component to detect each boundary of said nonlinear characteristic of coupling means between said motor and an injection cylinder and to produce a boundary signal representative of each boundary; and
45 gain selecting means (44) responsive to said boundary signal to select an optimum gain among said plurality of gains memorized in said gain memorizing means (43).
5. Injection molding machine as claimed in Claim 4, wherein said state detecting means (50) is supplied with a feedback value and a desired value and includes differentiating means for differentiating a difference between said feedback value and said desired value.
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6. Injection molding machine as claimed in Claim 4 or 5, wherein said state detecting means (50) includes screw velocity detecting means (51) for detecting a movement velocity of a screw as a detected screw velocity, reference value producing means (52) for producing a screw velocity reference value, and comparing means (53) for comparing
55 said detected screw velocity and said reference value.
7. Injection molding machine as claimed in Claim 4 or 5, wherein said state detecting means (50) includes screw velocity detecting means (51) for detecting a movement velocity of a screw as a detected screw velocity, motor

velocity detecting means (54) for detecting a velocity of the screw driving motor (11) as a detected motor velocity, and subtracting means (55) for calculating a difference between said detected screw velocity and said detected motor velocity.

- 5 8. Injection molding machine as claimed in any one of Claims 4 to 7, wherein said state detecting means (50) includes load pressure detecting means (56) for detecting a load pressure and motor torque detecting means (57) for detecting a torque of the screw driving motor (11).

Patentansprüche

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1. Spritzgußmaschine gesteuert von einem elektrischen Servomotor (11) mit einer Verstärkungs-Bereitstellungseinrichtung (45) zum Bereitstellen einer Verstärkung für den dem Motor zugeführten Strom, einer Grenzwertdetektionseinrichtung (42) zum Unterteilen einer nichtlinearen Charakteristik einer nichtlinearen Komponente einer Kopplungseinrichtung zwischen dem Motor und einem Einspritzzylinder (20), um jeden Grenzwert der nichtlinearen Charakteristik zu detektieren und einen jeden Grenzwert repräsentierendes Grenzwertsignal zu erzeugen, und einer Verstärkungsänderungseinrichtung (46), die auf das Grenzwertsignal reagiert, um die Verstärkung der Verstärkungs-Bereitstellungseinrichtung (45) bezogen auf das Grenzwertsignal zu verändern.

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2. Spritzgußmaschine nach Anspruch 1, wobei die Verstärkungs-Bereitstellungseinrichtung (45) dazu dient, eine Grundverstärkung als besagte Verstärkung bereitzustellen;

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wobei die Grenzwertdetektionseinrichtung (42) aufweist:

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eine Betriebsablaufmuster-Erzeugungseinrichtung (24-2) zum Erzeugen eines Betriebsablaufmusters; und
eine Differenzierungseinrichtung (31) zum Berechnen eines Differentialwertes des Betriebsablaufmusters, um den Differentialwert als das Grenzwertsignal zu erzeugen;
wobei die Verstärkungsänderungseinrichtung (46) auf den Differentialwert des Betriebsablaufmusters reagiert, um sukzessiv die Grundverstärkung bezogen auf einen Wert zu ändern, der berechnet wird, wenn der Differentialwert Null ist.

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3. Spritzgußmaschine nach Anspruch 1 oder 2, wobei die Spritzgußmaschine eine Form aufweist, in welche Harz eingespritzt wird:

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wobei die Verstärkungs-Bereitstellungseinrichtung (45) eine Grundverstärkung bereitstellt;

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die Grenzwertdetektionseinrichtung (42) aufweist:
eine Meßeinrichtung (63) zum Messen eines Zeitablaufs vom Beginn der Einspritzung, um ein Meßergebnissignal zu erzeugen, das den Ablauf der Zeit angibt;
wobei die Verstärkungsänderungseinrichtung (46) auf das Meßergebnis reagiert, um sukzessiv die Grundverstärkung bezogen auf eine Stabilitätsgrenzverstärkung zu ändern, die erhalten wird, wenn das Harz in der Form vollständig verfestigt ist.

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4. Spritzgußmaschine gesteuert von einem elektrischen Servomotor (11) mit:

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einer Zustandsdetektionseinrichtung (50) zum Detektieren eines Ergebnisses der Regelung der Spritzgußmaschine, um ein Detektionssignal zu erzeugen, das das Ergebnis der Regelung anzeigt;
einer Verstärkungsspeichereinrichtung (43) zum Speichern mehrerer Verstärkungen für den Motor (11);
einer Grenzwertdetektionseinrichtung (42), die mit einem Signal aus der Zustandsdetektionseinrichtung zum Unterteilen einer nichtlinearen Charakteristik einer nichtlinearen Komponente beliefert wird, um jeden Grenzwert der nichtlinearen Charakteristik der Kopplungseinrichtung zwischen dem Motor und einem Einspritzzylinder zu detektieren und um ein jeden Grenzwert repräsentierendes Grenzwertsignal zu erzeugen; und
einer Verstärkungsauswahleinrichtung (44), die auf das Grenzwertsignal reagiert, um eine optimale Verstärkung aus den mehreren in der Verstärkungsspeichereinrichtung (43) gespeicherten Verstärkungen auszuwählen.

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5. Spritzgußmaschine nach Anspruch 4, wobei die Zustandsdetektionseinrichtung (50) mit einem Rückkopplungswert und einem Sollwert beliefert wird und eine Differenzierungseinrichtung zum Differenzieren einer Differenz zwi-

schen dem Rückkopplungswert und dem Sollwert aufweist.

6. Spritzgußmaschine nach Anspruch 4 oder 5, wobei die Zustandsdetektionseinrichtung (50) eine Spindelgeschwindigkeitsdetektionseinrichtung (51) zum Detektieren einer Bewegungsgeschwindigkeit einer Spindel als einer detektierten Spindelgeschwindigkeit, eine Referenzwerterzeugungseinrichtung (52) zum Erzeugen eines Spindelgeschwindigkeitsreferenzwertes, und eine Vergleichseinrichtung (53) zum Vergleichen der Spindelgeschwindigkeit und des Referenzwertes aufweist.

7. Spritzgußmaschine nach Anspruch 4 oder 5, wobei die Zustandsdetektionseinrichtung (50) eine Spindelgeschwindigkeitsdetektionseinrichtung (51) zum Detektieren einer Bewegungsgeschwindigkeit einer Spindel als einer detektierten Spindelgeschwindigkeit, eine Motorgeschwindigkeitsdetektionseinrichtung (54) zum Detektieren einer Geschwindigkeit des Spindelantriebsmotors (11) als einer detektierten Motorgeschwindigkeit, und eine Subtraktionseinrichtung (55) zum Berechnen einer Differenz zwischen der detektierten Spindelgeschwindigkeit und der detektierten Motorgeschwindigkeit aufweist.

8. Spritzgußmaschine nach einem der Ansprüche 4 bis 7, wobei die Zustandsdetektionseinrichtung (50) eine Lastdruckdetektionseinrichtung (56) zum Detektieren eines Lastdrucks und eine Motordrehmomentdetektionseinrichtung (57) zum Detektieren eines Drehmoments des Spindelantriebsmotors (11) aufweist.

Revendications

1. Machine de moulage par injection commandée par un moteur d'asservissement électrique (11) comprenant un moyen de production de gain (45) destiné à fournir un gain au courant fourni audit moteur, un moyen de détection de limite (42) destiné à diviser une caractéristique non linéaire d'une composante non linéaire d'un moyen d'accouplement entre ledit moteur et un cylindre d'injection (20) afin de détecter chaque limite de ladite caractéristique non linéaire et de produire un signal de limite représentatif de chaque limite, et un moyen de modification de gain (46) répondant audit signal de limite afin de modifier ledit gain dudit moyen de production de gain (45) en se référant audit signal de limite.

2. Machine de moulage par injection selon la revendication 1, dans laquelle ledit moyen de production de gain (45) est destiné à fournir un gain de base en tant que dit gain,

ledit moyen de détection de limite (42) comprenant :

un moyen de production de profil de fonctionnement (24-2) destiné à produire un profil de fonctionnement, et
un moyen de différenciation (31) destiné à calculer une valeur différentielle dudit profil de fonctionnement afin de produire ladite valeur différentielle en tant que dit signal de limite,
ledit moyen de modification de gain (46) répondant à ladite valeur différentielle dudit profil de fonctionnement afin de modifier successivement ledit gain de base en se référant à une valeur calculée lorsque ladite valeur différentielle est égale à zéro.

3. Machine de moulage par injection selon la revendication 1 ou 2, ladite machine de moulage comprenant un moule dans lequel de la résine est injectée,

ledit moyen de production de gain (45) fournissant un gain de base,

ledit moyen de détection de limite (42) comprenant :
un moyen de mesure (63) destiné, à mesurer un intervalle de temps à partir du début de l'injection afin de produire un signal de résultat de mesure indicatif dudit intervalle de temps,
ledit moyen de modification de gain (46) répondant audit résultat de mesure pour modifier successivement ledit gain de base en se référant à un gain de limite de stabilité obtenu lorsque ladite résine s'est complètement solidifiée dans ledit moule.

4. Machine de moulage par injection commandée par un moteur d'asservissement électrique (11) comprenant :

un moyen de détection d'état (50) destiné à détecter un résultat de commande de ladite machine de moulage par injection afin de produire un signal de détection indicatif dudit résultat de la commande,

un moyen de mémorisation de gain (43) destiné à mémoriser une pluralité de gains dudit moteur (11),
 un moyen de détection de limite (42) recevant un signal dudit moyen de détection d'état destiné à diviser une
 caractéristique non linéaire d'une composante non linéaire afin de détecter chaque limite de ladite caractéris-
 tique non linéaire d'un moyen d'accouplement entre ledit moteur et un cylindre d'injection et afin de produire un
 signal de limite représentatif de chaque limite, et
 un moyen de sélection de gain (44) répondant audit signal de limite pour sélectionner un gain optimum parmi
 ladite pluralité de gains mémorisés dans ledit moyen de mémorisation de gain (43).

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5. Machine de moulage par injection selon la revendication 4, dans laquelle ledit moyen de détection d'état (50) reçoit
 une valeur de contre-réaction et une valeur désirée et comprend un moyen de différenciation destiné à différencier
 une différence entre ladite valeur de contre-réaction et ladite valeur désirée.

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6. Machine de moulage par injection selon la revendication 4 ou 5, dans laquelle ledit moyen de détection d'état (50)
 comprend un moyen de détection de vitesse de vis (51) destiné à détecter une vitesse de déplacement d'une vis
 en tant que vitesse de vis détectée, un moyen de production de valeur de référence (52) destiné à produire une
 valeur de référence de vitesse de vis, et un moyen de comparaison (53) destiné à comparer ladite vitesse de vis
 détectée et ladite valeur de référence.

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7. Machine de moulage par injection selon la revendication 4 ou 5, dans laquelle ledit moyen de détection d'état (50)
 comprend un moyen de détection de vitesse de vis (51) destiné à détecter une vitesse de déplacement d'une vis
 en tant que vitesse de vis détectée, un moyen de détection de vitesse de moteur (54) destiné à détecter une vitesse
 du moteur d'entraînement de la vis (11) en tant que vitesse de moteur détectée, et un moyen de soustraction (55)
 destiné à calculer une différence entre ladite vitesse de vis détectée et ladite vitesse de moteur détectée.

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8. Machine de moulage par injection selon l'une quelconque des revendications 4 à 7, dans laquelle ledit moyen de
 détection d'état (50) comprend un moyen de détection de pression de charge (56) destiné à détecter une pression
 de charge ainsi qu'un moyen de détection de couple de moteur (57) destiné à détecter le couple du moteur d'entraî-
 nement de vis (11).

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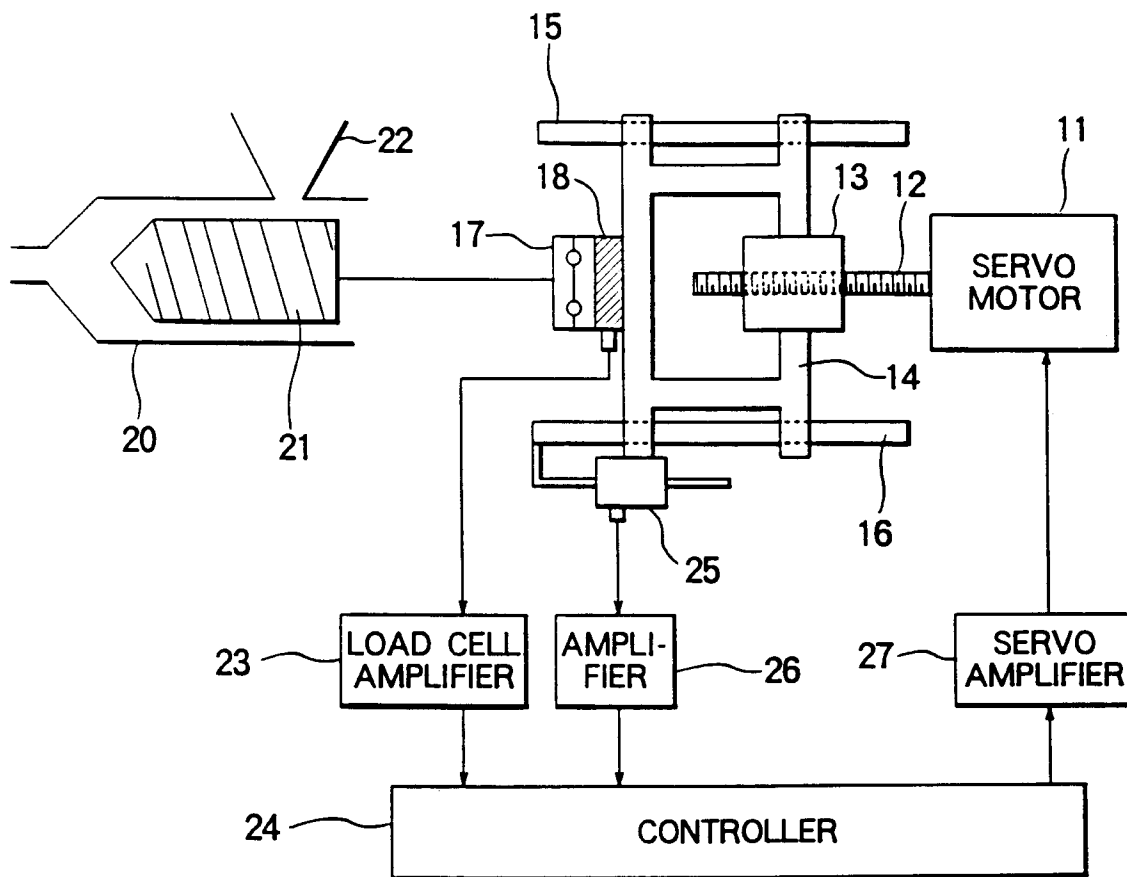


FIG. 1 PRIOR ART

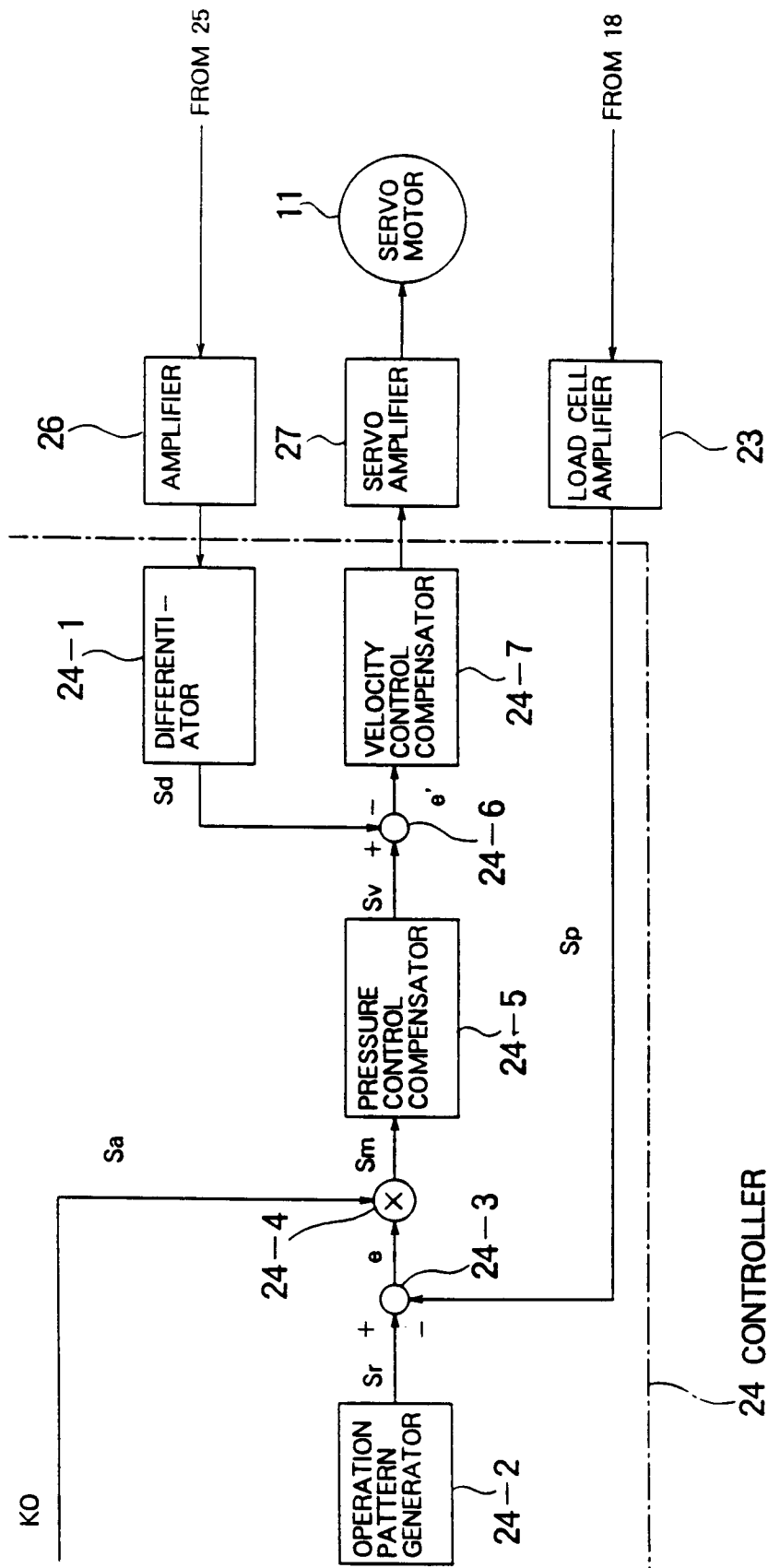


FIG. 2 PRIOR ART

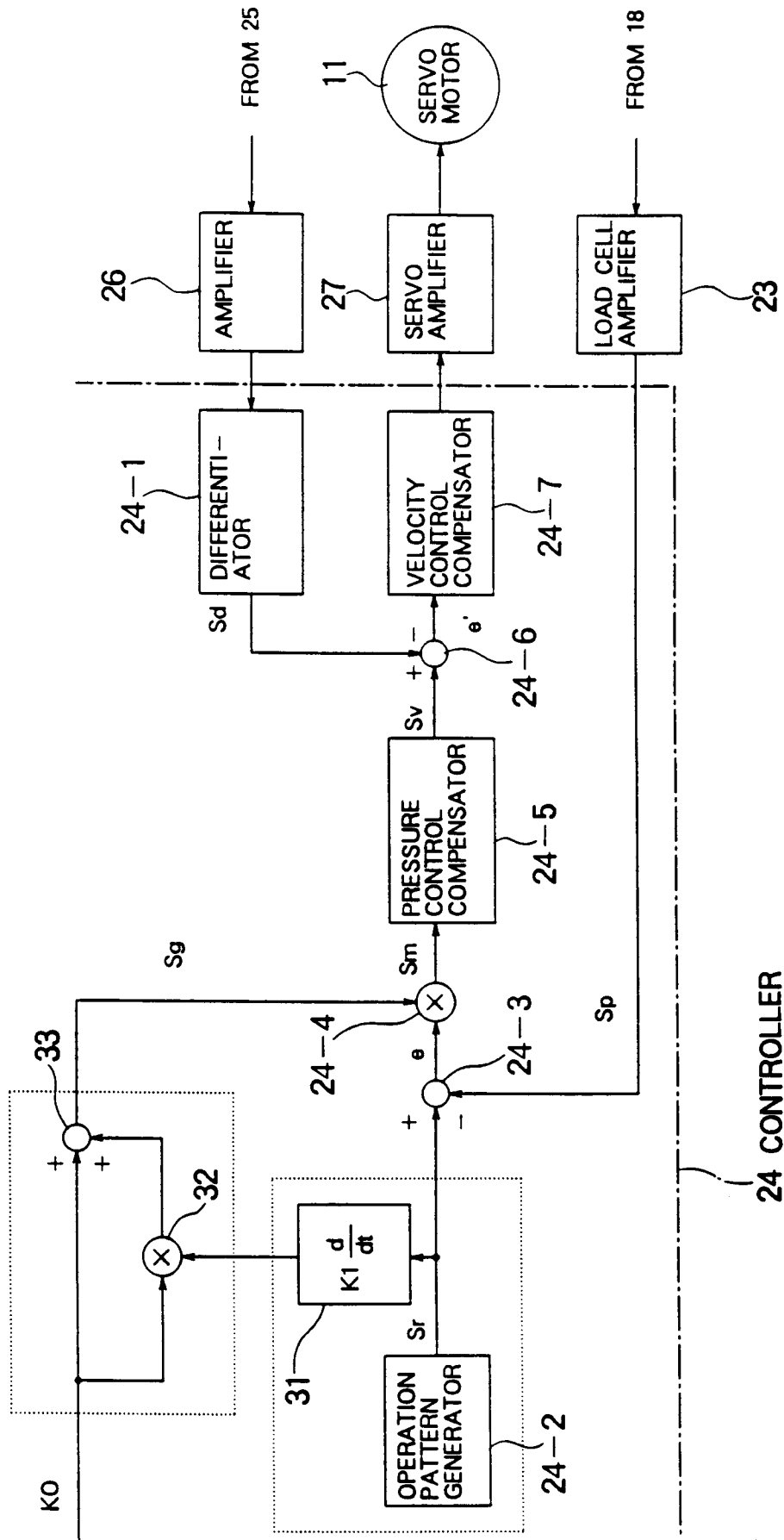


FIG. 3

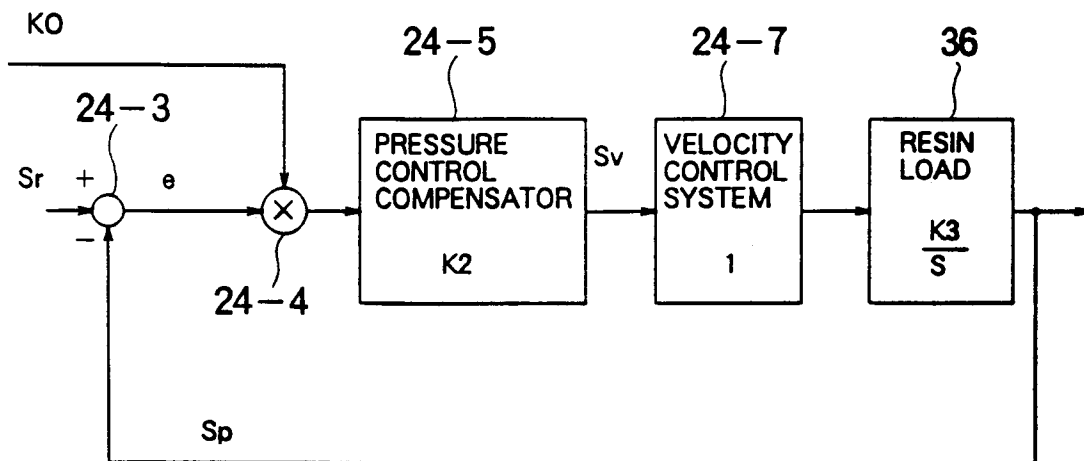


FIG. 4

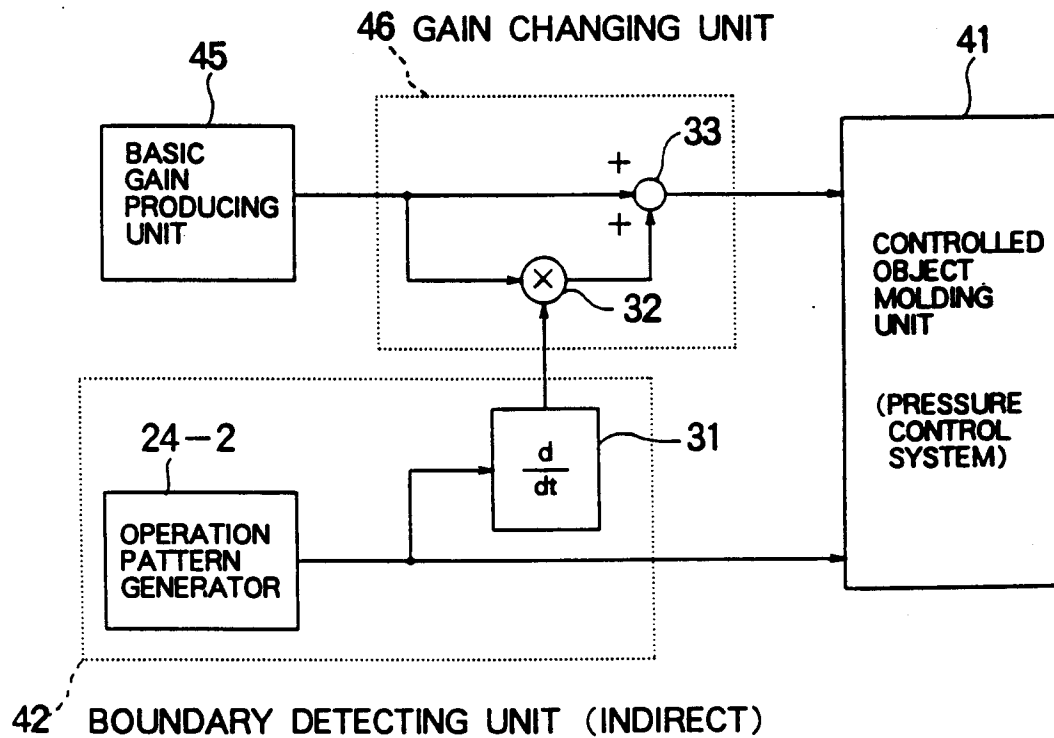


FIG. 5

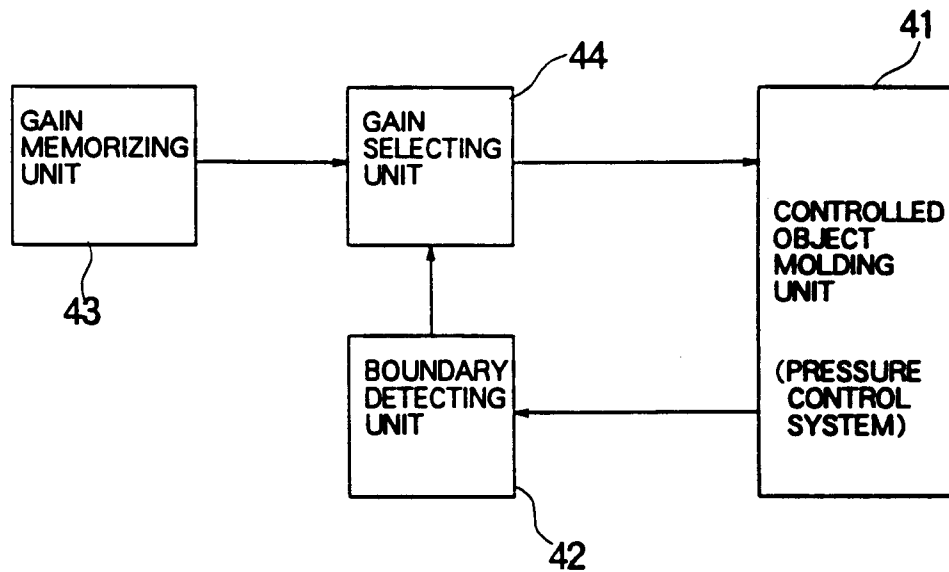


FIG. 6

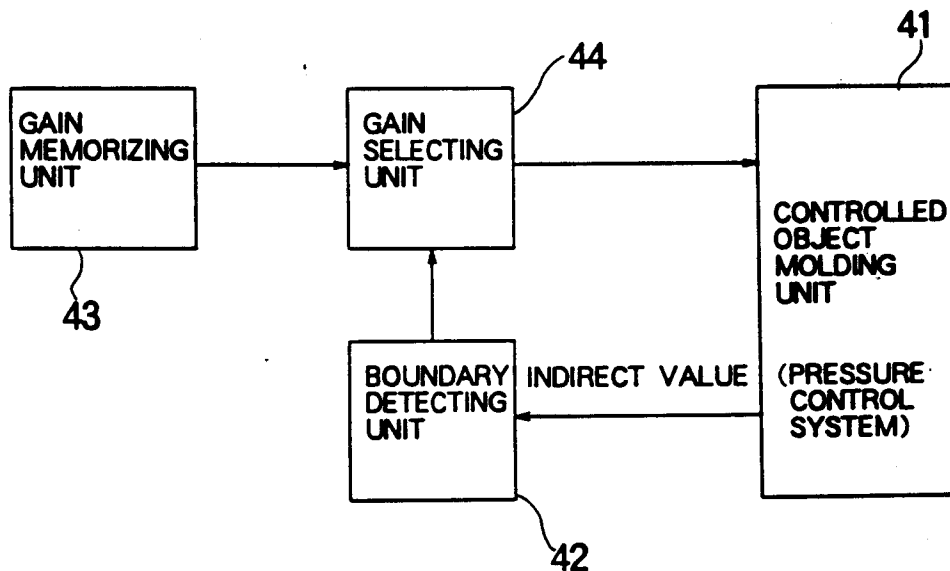


FIG. 7

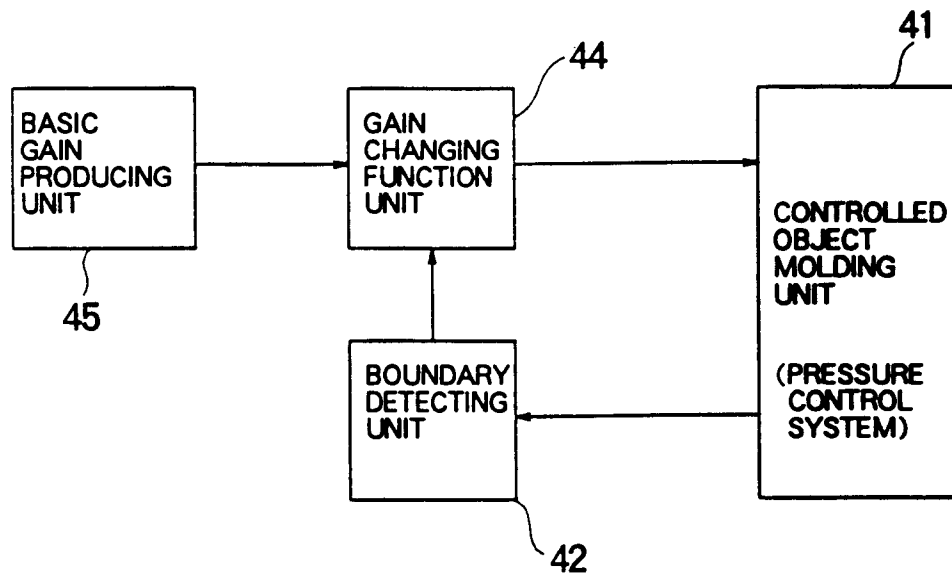


FIG. 8

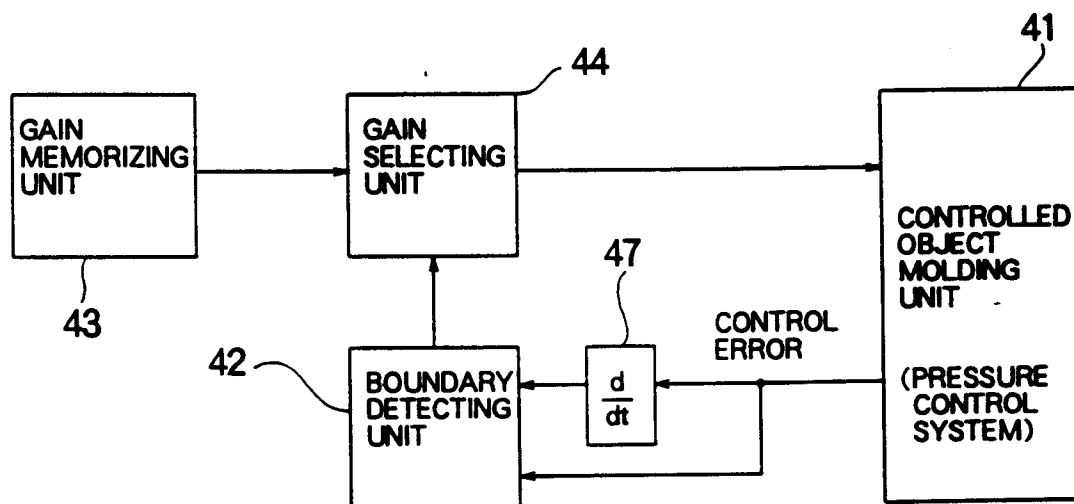


FIG. 9

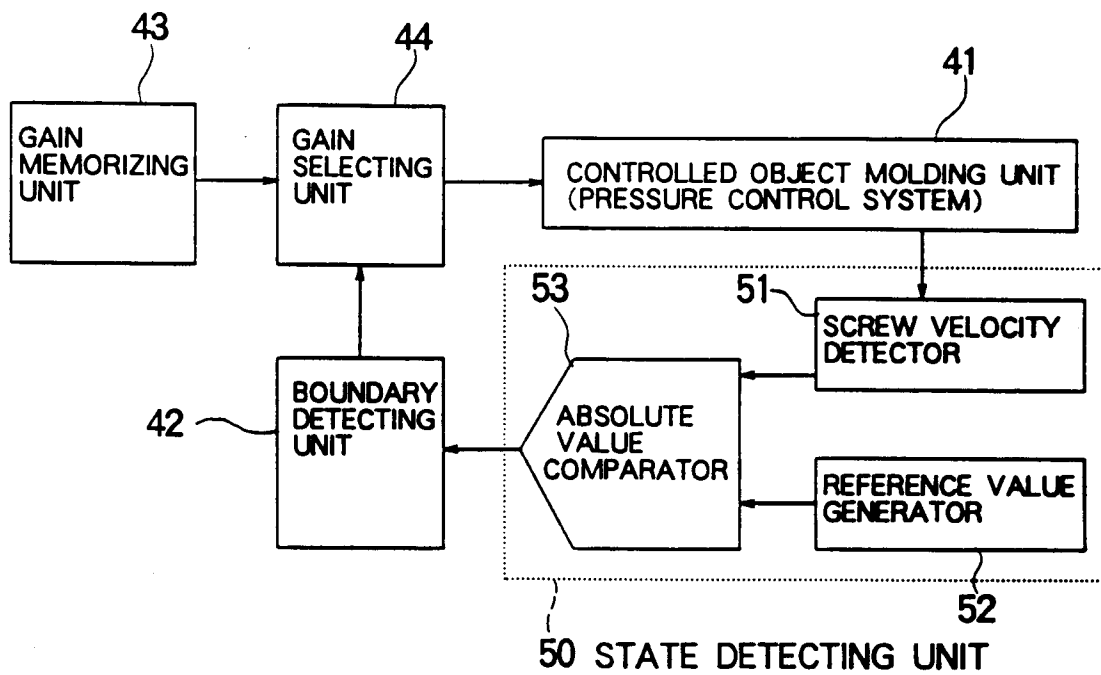


FIG. 10

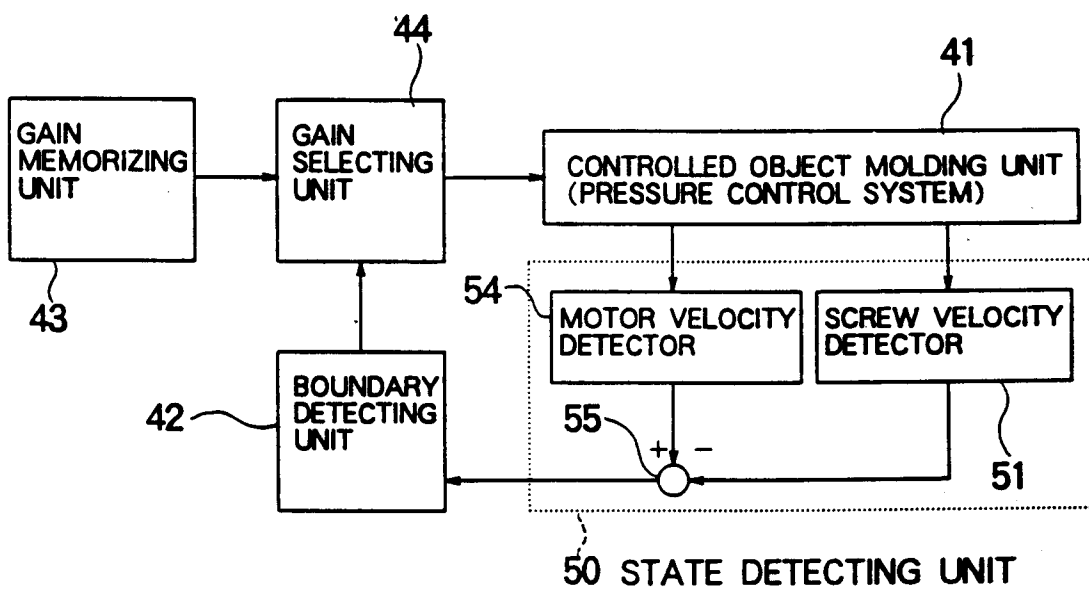


FIG. 11

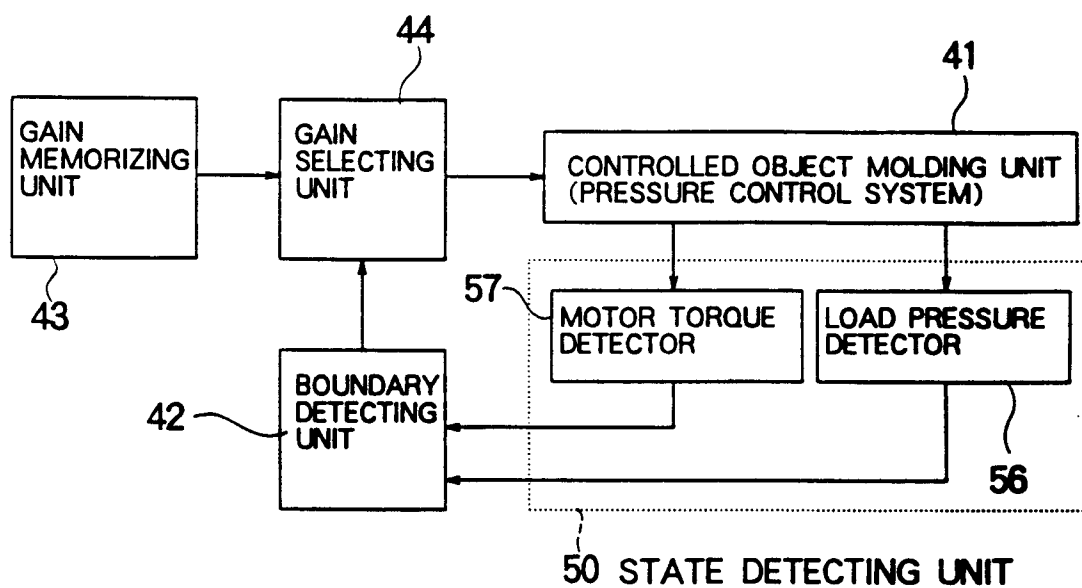


FIG. 12

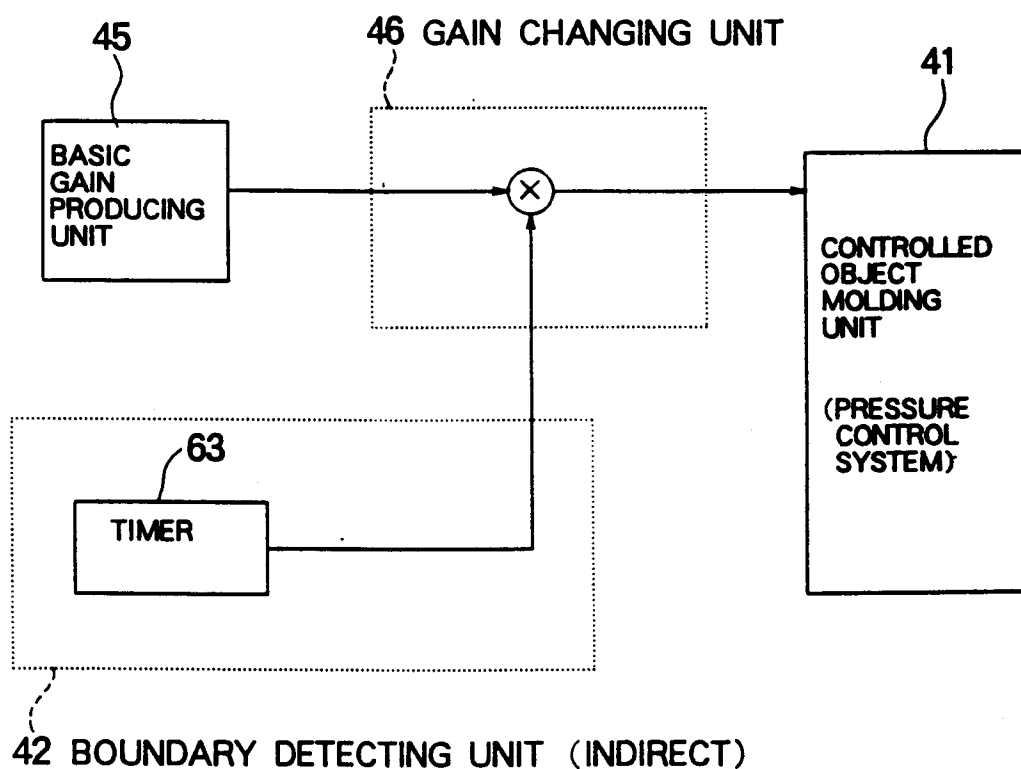


FIG. 13